

ENTOMOLOGY.—*The immature stages of Sarcophaga cooleyi, S. bullata, and S. shermani (Diptera: Sarcophagidae).* VERNE F. NEWHOUSE, DAVID W. WALKER, and MAURICE T. JAMES, State College of Washington.

This paper describes the immature stages of three species of saprophagous flies, *Sarcophaga cooleyi* Parker, *S. bullata* Parker, and *S. shermani* Parker. These flies show an extremely close relationship to one another as adults, and this affinity is even more completely borne out by comparative study of their larval stages.

Greene (1925) described briefly and illustrated the puparia of *Sarcophaga cooleyi* and *S. bullata*. The larva of *S. bullata*, undoubtedly third stage though not expressly so stated, is also briefly discussed and figured. Knipling (1936) described more fully the first instar of *S. bullata*, in comparison with some other species of the same genus, and illustrated the cephalopharyngeal apparatus, the entire larva, and the pattern and morphology of the setulae. Root (1923) discussed the morphology and specific characters of sarcophagid larvae including *bullata*, with special emphasis on spiracular characters. As far as we can ascertain there has been no published study of the larval forms of *S. shermani*.

This present study was initiated with the hope of distinguishing more clearly these important, closely related species and of facilitating their identification in the future.

A great amount of the preliminary work on this study was done during the summer of 1951 by David W. Walker and presented in a thesis submitted as partial fulfillment of requirements for a M.S. degree in entomology at the State College of Washington. Material for Mr. Walker's study, as well as for this one, was obtained through studies supported in part by funds provided for biological and medical research by the State of Washington, Initiative Measure no. 171.

MATERIALS AND METHODS

Material for study was taken from laboratory colonies, reared at the State College of Washington, from stocks originally collected in various areas of the State. Samples were taken from well established colonies which had been carried through as many as 27 generations. Although larvae of all ages

were examined, the most fully developed of each instar were selected wherever possible as it was felt that this would show most typically the anatomical characters of that instar.

In all stages of all species except one (*Sarcophaga bullata*) second instar, of which 18 specimens were studied), at least 50 and as many as 300 specimens were examined.

For fixation, eggs and larvae were placed in water and heated to the boiling point for 30 seconds. The water was then decanted and the specimens were carried through 70 per cent alcohol for 24 hours, into absolute alcohol for a similar time period, drained, placed in xylene for 24 hours, and finally stored in clove oil. Those for gross examination were retained in 70 per cent alcohol. Larvae for the purpose of illustration were removed from alcohol, cut in half, and boiled in concentrated potassium hydroxide until the integument was clear and the body contents removed. The cephalopharyngeal apparatus was examined under clove oil at magnification of 45 diameters, and all drawings were made with the aid of a micrometer grid. As sarcophagid flies are normally larviparous, eggs were obtained by dissection or by forcing them from the abdomen of gravid flies before the development of the larvae.

Sarcophaga cooleyi Parker

Sarcophaga cooleyi Parker, Can. Ent. 46: 417-423. 1914.

Egg.—White; smooth; slightly curved, tapered moderately toward one end. Length 1.10 mm, diameter 0.333 mm.

First stage larva.—White; muscidiform; length 1.50 to 4.75 mm, diameter 0.75 mm; cuticle nearly smooth. Anterior and/or posterior margin of each segment possessing many hooklike setulae arranged around the segmental circumference in the form of a band. Spinous bands very prominent; setulae dark brown in color; bands complete on segments 2 through 12. Band on segment 2 (first thoracic) very broad, especially ventrally just posterior to mouth hooks. Bands

on anterior margins usually complete on segments 2 through 9; incomplete on segments 10 through 12. Bands on posterior margins usually absent on segments 2 through 4; complete on segments 9 through 11; and incomplete on segments 5 through 8. Dorsal and lateral portions of bands on segments 5 through 12 not as heavy or dark as on the more anterior segments. Larvae metapneustic; prothoracic spiracles non-functional but may be visible beneath integument, especially just before the molt. Caudal pair of spiracles situated in a shallow cavity, each unit consisting of two elongated spiracular openings lying side by side, their inner sides confluent and their axis dorsoventral. Distance between each spiracle approximately equal to the width of one spiracle. Peritreme absent. Posterior tubercles weakly developed; may appear to be absent. Opening of spiracular cavity bordered with nearly complete ring of setulae or darkened cuticular papillae. Anal tubercles small but prominent. Anal opening surrounded by patch of black setulae.

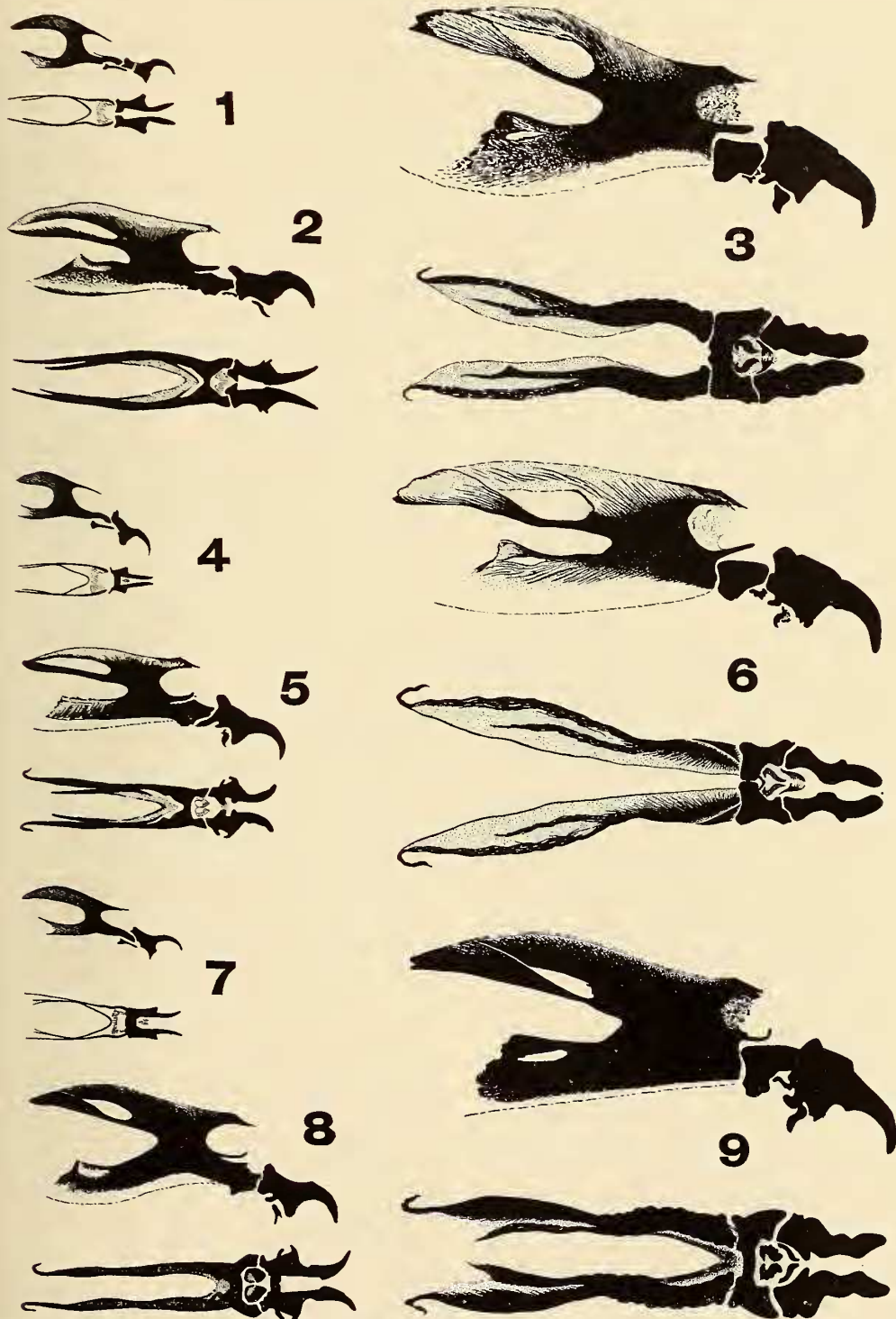
Cephalopharyngeal skeleton (Fig. 1).—Labial sclerite well formed, heavily pigmented. Mouth hooks fused, or in process of fusing posteroventrally. Hooks arising from anterodorsal corner of sclerite, extending forward in a smooth even curve, terminating in a sharp point above the median longitudinal axis of the sclerite.¹ Anterior lower edge of sclerite more or less sharp and truncate. Hypostomal sclerite small; from a lateral aspect wedge-shaped, broadened posteriorly, narrowed anteriorly; from a ventral aspect much less pigmented, broad and thick posteriorly, extending anteriorly as two thin lateral processes. Small accessory sclerite between mouth hooks not visible. Dental sclerite apparently absent. Pharyngeal sclerite well developed; well pigmented. Anterior process of ventral portion possessing a small sclerotized extension which protrudes posteriorly. Upper posterior end of ventral cornu heavily pigmented, protruding upward and outward beyond lower edge. Over-all length of skeleton 0.455 to 0.546 mm.

Second stage larva.—White; muscidiform; length 5.0 to 9.0 mm, diameter 0.75 to 1.75 mm. Entire cuticle covered with minute papillae

except the anterior margin of each segment which possesses many hookline setulae; anterior spinous bands prominent, setulae dark brown in color. Lateral margins of oral opening possessing minute ridges which radiate from the opening. Band on segment 2 sometimes divided, either with a heavy patch of setulae dorsally and ventrally, or with the band complete but with its lateral portions weakly developed; band sometimes obscured as a result of retraction of the cephalic segment. Bands on anterior margins usually complete on segments 2 through 9 or 10; incomplete on segments 10 or 11 through 12. Bands on posterior margins usually absent on segments 2 through 4; incomplete on segments 5 through 7; complete on segments 8 through 11. Larvae amphipneustic; prothoracic spiracle near posterior margin of segment 2 (first thoracic), prominently divided into 12 to 15 digits, each terminating in an oval spiracular opening. Caudal spiracles, each composed of two slit-like openings, situated in a deep cavity; peritreme present but weakly developed. Spiracles almost contiguous at upper inner border. Posterior tubercles humplike; posterior cavity bordered with complete ring of setulae or darkened integumental papillae. Anal tubercles prominent and fingerlike. Anal opening surrounded by small patch of black setulae.

Cephalopharyngeal skeleton (Fig. 2).—Labial sclerite heavy, deeply pigmented; hook extending from upper anterior corner of sclerite outward and downward in a smooth curve, but terminating above the median longitudinal axis of the sclerite. Lower anterior corner of sclerite possessing a rounded toothlike protuberance; the sliverlike dental sclerite clearly visible just posterior to this protuberance. Accessory sclerite slender, lying between posterior ends of labial sclerites, extending downwards below the edge of the labial sclerite so as to give the impression of a small ventral process on the sclerite when viewed from a lateral aspect. Hypostomal sclerite narrowed anteriorly, fused basely to the pharyngeal sclerite. Paired infrahypostomal sclerites weakly developed, lightly pigmented; visible from dorsal aspect between anterior arms of hypostomal sclerite. Pharyngeal sclerite lightly pigmented; parastomal sclerite rather thick, blunt; dorso-pharyngeal sclerite lightly pigmented, flattened anteriorly. Ventral cornu thickened posteriorly; the upper edge bending dorsally and possessing a small, weakly developed fenestra, the lower edge

¹ The median longitudinal axis is here defined as a line drawn through the body of the sclerite from back to front midway between the posterior corners and roughly parallel to the lower edge.



FIGS. 1-9.—Cephalopharyngeal skeletons of *Sarcophaga*, lateral (upper figure) and ventral (lower figure) views: 1, *S. cooleyi*, first instar; 2, same, second instar; 3, same, third instar. 4, *S. bullata*, first instar; 5, same, second instar; 6, same, third instar. 7, *S. shermani*, first instar; 8, same, second instar; 9, same, third instar. Drawn by Verne F. Newhouse. Drawings in each case based on representative specimens of the series studied.

extending posteriorly. Over-all length of skeleton usually about 0.966 mm.

Third stage larva.—White, muscidiform; length 8.75 to 20.25 mm; at maturity (average of 10) 19.17 mm. Diameter 1.5 to 4.5 mm. Entire cuticle covered with minute papillae except the anterior margin of each segment which possesses many hooklike setulae. Spinous band on segment 2 (first thoracic) incomplete; large patch of setulae posterior to mouth hooks, similar patch dorsally but lateral extensions of band incomplete. Oral margin possessing small ridges which radiate from the oral cavity, extending well laterally on the cephalic segment. Spinous bands complete on segments 2 through 12. Bands on anterior margins usually complete on segments 2 through 10; incomplete on segments 11 and 12. Bands on posterior margins usually absent on segments 2 through 4; incomplete on segments 5 through 8; and complete on segments 9 through 11. Prothoracic spiracles prominent, divided into 9 to 17 digits, but more commonly into 14 to 16. Caudal spiracles, each divided into three slit-like openings, situated in a deep cavity. Peritreme prominent, strongly developed; extending dorsally and medially to form a rather sharp upper inside angle, then laterally and ventrally in a rather regular curve to terminate directly beneath the innermost slit. Ratio of width of one spiracle to distance between spiracles 5.77 to 3.75 (average of 10). Posterior tubercles slender and fingerlike. Spiracular cavity bordered by ring of microscopic setulae or dark papillae. Anal tubercles large and fingerlike, depending from a prominent anal process. Anal opening surrounded by small patch of black setulae in contrast to colorless setulae of body in general.

Cephalopharyngeal skeleton (Fig. 3).—Labial sclerite strongly developed, heavily pigmented; hook arising from upper anterior angle of sclerite, extending straight outward, then bending downward in a rather sharp curve. Front angle below tooth sharp, truncate. Dental sclerite strongly developed. Accessory sclerite protrudes below lower edge of labial sclerite, appearing from lateral aspect as a process of that sclerite. Hypostomal sclerite roughly rectangular, more narrowed anteriorly than posteriorly. Paired infrahypostomal sclerites visible between and below arms of hypostomal sclerite. Pharyngeal sclerite heavily pigmented medially, but lightly pigmented distally. Dorsopharyngeal sclerite lightly pigmented except for extreme upper anterior

flattened area. Parastomal sclerite rather heavy, blunt. Dorsal cornu possessing an elongated, narrow fenestra; ventral cornu thickened posteriorly, possessing a small, weakly developed fenestra in upper posterior corner. Lower edge of ventral cornu (sometimes almost indiscernible) convex. Lines of axis of dorsal and ventral cornu divergent posteriorly. Overall length of skeleton usually about 1.70 mm.

Pupa.—Elliptical, dull dark red; 8.5 to 11 mm in length, 3 to 5 mm in diameter. Opening of spiracular cavity oval to elliptical. Spiracular plate on roof of posterior cavity shining deep red-brown; slits almost white in contrast. Tubercles surrounding posterior cavity flattened, distorted. Anal tubercles prominent. Posterior tubercles connected to anal tubercles by a broad, rounded ridge. Spinous bands complete on segments 3 through 12. Prothoracic spiracles evident, but number of digits usually not discernible.

Sarcophaga bullata Parker

Sarcophaga bullata Parker, Can. Ent. **48**: 359-364. 1916.

Egg.—Unfertilized egg at time of copulation white, translucent; 0.49 mm in length, 0.30 mm in diameter. Shape almost as hen's egg. Entire surface covered with minute depressions or pits.² Mature egg as in *cooleyi*; length 1.25 mm. Distinctly tapered anteriorly. Developing larva distinctly visible within.

First stage larva.—White, muscidiform, as in *cooleyi*. Newly hatched larva 2 to 2.5 mm in length; 0.5 mm in diameter. Spinous bands considerably more prominent than in *cooleyi*, almost black in color; not divided to as great an extent by plicae except ventrally. Bands on anterior margins usually complete on segments 2 through 7; incomplete on segments 8 through 10; and absent on segments 11 and 12. Bands on posterior margins usually absent on segments 1 through 6; incomplete on segments 5 through 8; and complete on segments 9 through 11. Anal tubercles more fingerlike than in *cooleyi*.

Cephalopharyngeal skeleton (Fig. 4).—Labial sclerite well developed. Mouth hook arising as in *cooleyi*, but more slender and raised higher from median longitudinal axis of sclerite. Posterior

² This degree in development unfortunately could not be accurately matched in the other species, therefore cannot be compared.

articulation process extending laterally, very slender. Accessory sclerite visible between labial sclerites. Hypostomal sclerite thickened posteriorly. Anterior extensions of ventral cornu not possessing a dorsal process. Pharyngeal sclerite smaller and lighter in pigment than in *cooleyi*. Ventral cornu not extending dorsally, but appearing bifurcated apically as a result of incomplete sclerotization. Over-all length of skeleton 0.433 mm.

Second stage larva.—Much as in *cooleyi*. Larva apparently slightly larger. Length 5.25 to 9.25 mm, diameter 0.75 to 2.25 mm. Setulae of cuticle black; bands on segments 2 through 12 complete. Band on segment 2 very broad, especially ventrally. Bands on anterior margins usually complete on segments 2 through 7; incomplete on segments 10 through 12. Bands on posterior margins usually absent on segments 2 through 4; incomplete on segments 5 through 8, complete on segments 9 through 11. Narrow band of setulae partially surrounding base of anal prominence.

Cephalopharyngeal skeleton (Fig. 5).—Labial sclerite more slender than in *cooleyi*. Hook extending below the median longitudinal axis of the sclerite. Small tooth on lower anterior edge of sclerite more prominent, sharper than in *cooleyi*. Dental sclerite obvious. Slender accessory sclerite larger, extending more ventrad and caudad, appearing from lateral aspect as a long protuberance on labial sclerite. Hypostomal and infrahypostomal sclerites as in *cooleyi*. Pharyngeal sclerite lightly pigmented. Parastomal sclerite slender, usually bent up at the tip. Dorsopharyngeal sclerite more heavily pigmented, anterior flattening more pronounced. Dorsal and ventral cornua fenestrate; ventral cornu more slender, lower edge more straight than convex. Overall length of skeleton about 0.866 mm.

Third stage larva.—White, muscidiform, much as in *cooleyi*. Larva slightly larger; length 9.50 to 21.00 mm; at maturity (average of 10) 20.17 mm. Setulae of cuticle may show blackening of tips. Bands on anterior margins usually complete on segments 2 through 8; incomplete on segments 9 through 12. Bands on posterior margins usually absent on segments 2 through 4; incomplete on segments 5 through 7; complete on segments 8 through 11. Posterior tubercles fingerlike; anal tubercles long and prominent. Ratio of width of one spiracle to distance between spiracles 5.80 to 3.95 (average of 10).

Cephalopharyngeal skeleton (Fig. 6).—Labial

sclerites strongly developed. Hook arising from upper anterior angle, extending straight outward, then downward in a slightly more regular curve than in *cooleyi*. Dental sclerite slightly less developed. Accessory, hypostomal, and infrahypostomal sclerites as in *cooleyi*. Pharyngeal sclerite much more compressed. Parastomal sclerite more slender, usually tilted upward anteriorly. Dorsal and ventral cornua fenestrate. Lines of axis of dorsal and ventral cornu not divergent posteriorly, but roughly parallel. Overall length of skeleton 1.56 mm.

Pupa.—As in *cooleyi*; perhaps slightly larger. Length 9.5 to 11.5 mm.

Sarcophaga shermani Parker

Sarcophaga exuberans Authors (not Pandellé, Rev. Ent. **15**: 186. 1896).

Sarcophaga shermani Parker, Bull. Brooklyn Ent. Soc. **14**: 41–46. 1919; Ann. Mag. Nat. Hist. **9**(11): 124. 1923.

Egg.—Indistinguishable from *cooleyi*; length about 1.50 mm.

First stage larva.—As in *cooleyi*. Length of mature larva 5.50 mm, diameter 1.0 mm. Anal tubercles usually not as prominent as in *cooleyi*. Setulae of spinous bands black in color. Bands on anterior margins usually complete on segments 2 through 11; absent on segment 12. Bands on posterior margins absent on segments 2 through 4; incomplete on segment 5; complete on segments 6 through 11.

Cephalopharyngeal skeleton (Fig. 7).—Labial sclerite more slender than in either *cooleyi* or *bullata*; tooth arising at higher angle in relation to axis of sclerite. Dorsal cornu of pharyngeal sclerite relatively longer and more slender. Overall length of skeleton 0.533 mm.

Second stage larva.—As in *cooleyi*. Length 5.50 to 8.25 mm, diameter 1.0 to 1.75 mm. Spinous bands on anterior margins usually complete on segments 2 through 9 or 10; incomplete on segments 10 or 11 through 12. Bands on posterior margins absent on segments 2 through 4; incomplete on segments 5 through 7; complete on segments 8 through 11. Bands on second and third segments sometimes incomplete and indistinct. Posterior tubercles humplike but prominent; anal tubercles more fingerlike. Darkened band surrounding spiracular cavity not as prominent as in *cooleyi*. Narrow band of setulae at ventral base of anal tubercles.

Cephalopharyngeal skeleton (Fig. 8).—Labial

sclerite with hook arising at high angle. Dental, accessory, hypostomal and infrahypostomal sclerites prominent. Pharyngeal sclerite well formed and quite heavily pigmented. Dorsal and ventral cornua fenestrate. Cornua sometimes divergent posteriorly. Lower surface of ventral cornu almost concave in outline. Over-all length of skeleton 1.05 mm.

Third stage larva.—As in *cooleyi*. Length 8.00 to 18.00 mm, diameter 1.5 to 4.0 mm; at maturity (average of 10) 16.79 mm. Setulae of cuticle may be black at tip or colorless. Bands on anterior margins usually complete on segments 2 through 10; incomplete on segments 11 and 12. Bands on posterior margins usually absent on segments 2 through 4; incomplete on segments 5 through 7; complete on 8 through 11. Ratio of width of one spiracle to distance between spiracles 5.4 to 2.5. (Average of 10) One specimen, obviously atypical, was observed with three slits in the left spiracle and two in the right.

Cephalopharyngeal skeleton (Fig. 9).—Similar

to *cooleyi*. Mouth hook with small tooth on the underside at base. Dental sclerite robust. Parastomal sclerite slender and usually bent up at the tip. Pharyngeal sclerite quite heavily pigmented. Dorsal and ventral cornua fenestrate. Dorsal cornu comparatively more slender. Cornua divergent posteriorly. Lower edge of ventral cornu flattened or concave in profile. Over-all length of skeleton 1.43 mm.

Pupa.—As in *cooleyi*. Ridge connecting anal tubercles and posterior tubercles usually weakly developed or absent.

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ENTOMOLOGY.—*Some work of the periodical cicada*. E. A. ANDREWS, Johns Hopkins University. (Communicated by Paul H. Oehser.)

The periodical or seventeen-year cicada, found only in North America, has a subterranean life years longer than that of numerous other cicadas and an aerial life of a few months. Joining these two major parts of its life history are two briefer links: a few weeks late in summer when the eggs left by females inside the wood of twigs develop into minute young nymphs, which enter the ground; and a few weeks in spring when the subterranean nymphs come near the surface and become ready to emerge and transform into adults or imagoes. Some of the work done by the surface dwellers as observed at Baltimore, Md., is here described.

THE LAST DWELLING

During their years under ground the young cicadas shed from time to time, grow rapidly, and make successive mud dwellings attached to roots from which the nymphs suck their nutriment, being parasites upon many trees. In Baltimore Potter (1839) observed the largest of these dwellings some 18 inches below the surface. Each was a rough ball of earth $1\frac{1}{2}$ to 2 inches long and three-fourths of an inch wide, lined by smooth

mud, and contained one nymph. Emerging from such last feeding chambers the nymphs dig upward and construct somewhat different dwellings (Fig. 1). Within the mud tubes they rest some weeks till ready for emergence and transformation. These last dwellings have the advantage of safety some inches below the surface, along with quick access to the surface when the proper time comes. Each dwelling (Fig. 1) has rounded ends above and below as in previous subterranean dwellings, but these are connected by a long shaft and are commonly 150 to 350 mm long, though they may be longer or much shorter. In this shaft the lymph climbs up close to the surface or falls rapidly down to the bottom to escape attacks. In cross section the shaft is circular or sometimes elliptical, being wider than deep, and is about either 10 or 15 mm in diameter. Dwellings of these two sizes occur in the same places, but one or the other predominates, a fact that harmonizes with the occurrence here of a larger and a smaller variety of cicada of which one or the other is more abundant under certain trees. Also the larger bores were found where the larger cicadas emerged; that is, the bores were made to fit the cicadas.